Crime Networks with Bargaining and Build Frictions

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September 2008

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Abstract

How does the timing, targets and types of anti-crime policies affect a network when criminal retailers search sequentially for wholesalers and crime opportunities? Given the illicit nature of crime, I analyze a non-competitive market where players bargain over the surplus. In such a market, some anti-crime policies distort revenue sharing, reduce matching frictions and increase market activity or crime. As an application, the model provides a new perspective on why the U.S. cocaine market saw rising consumption after the introduction of the "War on Drugs."

JEL Classification Codes: C78, K42, L14

Keywords: crime, networks, search, matching

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1 Introduction

Economic theory argues that as the costs of crime rise then the quantity of crime falls. It follows that policies designed to increase the costs of crime will decrease the crime rate. However, how should these costs be imposed? For example, should law enforcement target wholesale drug dealers searching for retail dealers or should they target retailers who are selling to consumers? It can be shown that the choices regarding who to target, how to levy the costs, and when to act play a key role in determining the level of crime. At the extreme, I find increasing costs can increase market activity and crime.

Three features of the environment are critical to the findings. First, there is a network consisting of a wholesaler who authorizes or facilitates a criminal transaction and a retailer who carries out the act. Second, the retailer faces a series of matching frictions in creating a network and finding a crime opportunity where crime can be thought as selling drugs, prostitution, motor-vehicle theft, etc. Finally, wholesalers and retailers bargain over the surplus of the criminal activity. The market is assumed to be noncompetitive because crime is by definition illegal.

The results show anti-crime policies can have a range of effects depending upon their type, target and timing. For example, consider the tactic of plea bargaining with a retailer in exchange for evidence that leads to the prosecution of a wholesaler. In other words, a policy that increases the costs of apprehension to the wholesaler after the initial wholesale-retail connection is established. The result of such a policy distorts the retail-wholesale bargaining in favor of retail dealers. Intuitively, the wholesalers lower their price, or share of the surplus, because they want to complete the transaction faster. Therefore, an increase in the retailer's surplus increases the number of retailers and in turn the amount of criminal activity. Although the effects of certain policies go against the classical framework of supply and demand, many of the findings are in support of the canonical model. For example, if the value or revenue from crime goes up, then the level of crime rises. Alternatively, take drug trafficking and a policy in which law enforcement officers pose as wholesale dealers in order to sell and bust retailers. Such a policy targets the retailer by increasing the likelihood of apprehension during the initial stage of the networking process. The result of such a policy raises the retailer's fixed search costs. In other words, the policy would decrease the quantity of retailers, and in turn crime, while leaving the bargained price between the wholesaler and retailer unaffected. So, many of the classical results from the supply and demand model

continue to hold. However, it matters how policy makers impose costs on criminal networks, as they can distort the allocation of recourses within the network, the total number of criminals, and sometimes even increase the level of crime.

In relation to the literature, the matching frictions distinguish how the timing and type of policies affect supply rather than simply how targeting a key player will change the equilibrium, as discussed by Ballester, Calvó-Armengol & Zenou (2006) and others. In addition, the model provides a new understanding relative to Chiu, Mansley & Morgan (1998) who argue "the choice of battlefield [retail versus wholesale] on which to fight the war on drugs is likely to be of only secondary importance" (p. 108). Furthermore, the sequential series of matching frictions results in significantly different outcomes than search models of crime that posses two concurrent frictions.[1] For instance, Engelhardt, Rocheteau & Rupert (2008) find unequivocally that increasing the length of incarceration decreases crime when individuals are simultaneously searching for criminal activities and jobs. Besides the sequential matching frictions, bargaining plays a key role in the results. Relative to the literature, Desimone (2006) has investigated empirically whether the drug dealers split the surplus from the sale of drugs in an "additive" or "multiplicative" manner. Galenianos, Pacula & Persico (2007) consider how bargaining determines the purity and duration of a match in the retail market. Here, I add to the discussion by explicitly modeling the bargaining within a network and analyzing how changes in each individual's outside option, or the cost of searching for a new network, changes the quantity of crime.

As further motivation, the model provides a new prospective on the U.S. cocaine market during the 1980's. During the period, the U.S. "War on Drugs" effectively doubled the annual number of arrests and increased eight fold the number incarcerated for a drug related offense. At the same time, U.S. cocaine consumption rose.[2] The model below provides evidence that anti-drug policies could have distorted the market and increased the aggregate amount of drugs hitting the street. Intuitively, the U.S. government's action increased the likelihood of arrest and thus the costs for those trafficking across state lines. As a result, the wholesale dealers' bargaining position fell. The model's explanation is supported by the evidence that the share of revenue going to the street level dealer increased during this period. Hence, an increase in the retailer's share of the revenue might have increased the number of retail dealers and in turn illicit drug consumption. In Section 5, the

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[1]The results also differ from the literature dealing with how a network augments a single matching function, such as Calvó-Armengol & Zenou (2005), where they highlight how the rate of matching changes given a network.

[2]Refer to Section 5 for a more detailed discussion of the data.

argument is discussed in further detail.

In the next section, I introduce the model's environment and characterize the resulting equilibrium. Section 3 analyzes the effects from changing the expected costs to the network and Section 4 evaluates the efficiency of different policies.

2 Model

2.1 Environment

Time, t, is continuous and goes on forever. The economy is composed of a unit-measure of infinitely-lived wholesalers and a large measure of retailers. Both wholesalers and retailers are risk neutral and discount at rate $r > 0$. The two types of players network in three stages.

In the first stage, retailers and wholesalers risk being caught at the rate π_0, and if caught, pay F_0^v and F_0^w, respectively. The retailers enter freely and match with wholesalers through the matching technology $m_0(w_0, v_0)$, where v_0 and w_0 represents the mass of the retailers and wholesalers engaged in the initial search process. As is standard, the matching function is strictly increasing, strictly concave with respect to each of its arguments, and exhibits constant returns to scale. Furthermore, $m_0(0, \cdot) = m_0(\cdot, 0) = 0$ and $m_0(\infty, \cdot) = m_0(\cdot, \infty) = \infty$.

In the second stage, they again pay to search where search costs are in terms of being apprehended with probability π_1 and paying the cost F_1^v and F_1^w for the retailer and wholesaler, respectively. If the retail-wholesale pair is apprehended, then the network is destroyed. As in the first stage, the retail-wholesale network finds a crime opportunity through the technology $m_1(v_1, c_1)$ where v_1 is the measure of retailers with a wholesaler and c_1 is the measure of untaken crime opportunities. Crime opportunities can be thought of as a drug user who is continuously buying drugs.[3] Following the benchmark, m_1 is assumed to have the same characteristics as m_0. In addition, I assume retailers do not interfere with crime opportunities already being taken by other retailers.[4]

In the third stage, the wholesaler facilitates the crime at a fixed cost, y_p, and the crime produces output y for the wholesale-retail pair. At this point, the pair use Nash bargaining to divide the surplus y with the outside option being to look for a new crime opportunity. As a result, the retailer

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[3]Other examples include the prostitute-madam partnership with a steady client, or a Don-soldier relationship over a particular city. The model and its results can be applied to non-criminal environments as well.

[4]The assumption is based on how retailers protect their turf i.e. clientele or territory.

receives y_v share of the surplus while the wholesaler receives $y_w \equiv y - y_v - y_p$. At the same time, the retailer and wholesaler risk the loss of the crime opportunity in two ways. The network loses the crime opportunity exogenously at rate λ but keeps their association. Alternatively, the retailer and wholesaler run the risk of apprehension at rate π_2, lose the criminal opportunity along with their association, and pay the cost of being apprehended F_2^v and F_2^w, respectively.

This paper focuses on steady-state equilibrium where the distribution of crime opportunities and the measure of retailers is constant over time. Following the standard notation, the market tightness of the initial stage, $\theta_0 = \frac{v_0}{w_0}$, and second stage, $\theta_1 = \frac{v_1}{c_1}$ are time invariant. Therefore, a wholesaler matches with a retailer according to a Poisson process with arrival rate $\frac{m_0(v_0,w_0)}{w_0} \equiv \theta_0 q_0(\theta_0)$. Similarly, each retailer matches with a crime opportunity according to a Poisson process with arrival rate $\frac{m_1(v_1,c_1)}{v_1} \equiv q_1(\theta_1)$ and the retailer matches with the wholesaler at rate $\frac{m(v_0,w_0)}{v_0} \equiv q_0(\theta_0)$.

It is important to note that the model can change depending upon the assumptions made about the environment. For instance, the appendix introduces the free entry of wholesalers. Also, one could assume the outside position when bargaining is to destroy the network. However, I take the approach that retailers share a bond with the wholesaler and bargain with the option of giving up a particular opportunity.[5] In the end, these assumptions and their predictions should be tested as discussed in Section 5.

2.2 Bellman equations

In this section, I introduce the flow Bellman equations for a retailer and wholesaler. A retailer is in one of the following three states: searching for a wholesaler, matched with a wholesaler and searching for a criminal opportunity, or engaging in the criminal activity and splitting the surplus with the wholesaler. The value of being in each state $i \in \{0,1,2\}$ is denoted $\mathcal{V}_i$. The flow Bellman equations for a retailer are

$$
\begin{align}
r\mathcal{V}_0 &= \pi_0\left[-F_0^v - \mathcal{V}_0\right] + q_0(\theta_0)\left[\mathcal{V}_1 - \mathcal{V}_0\right], \tag{1}\\
r\mathcal{V}_1 &= \pi_1\left[-F_1^v - \mathcal{V}_1\right] + q_1(\theta_1)\left[\mathcal{V}_2 - \mathcal{V}_1\right], \tag{2}\\
r\mathcal{V}_2 &= y_v + \pi_2\left[-F_2^v - \mathcal{V}_2\right] + \lambda\left[\mathcal{V}_1 - \mathcal{V}_2\right]. \tag{3}
\end{align}
$$

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[5]Similarly, I assume wholesalers do not acquire their share of the surplus until the criminal opportunity is located. The assumption is motivated by the fact that wholesale cocaine dealers often provide their retailers with cocaine on credit and are paid after the sale.

Equation 1 shows that, initially, the retailer searches for a wholesaler to facilitate a criminal act. The retailer finds the wholesaler at rate $q_0(\theta_0)$ at which time the retailer enjoys a utility flow $[\mathscr{V}_1 - \mathscr{V}_0]$. However, at the same time the retailer faces the likelihood of apprehension, π_0, and if caught, pays the cost F_0^v and loses the asset value of being in the initial state. The second equation follows the same logic except the retailer is searching for a criminal opportunity. Finally, (3) demonstrates how the retailer has a criminal opportunity and receives the benefit y_v. However, the retailer faces the probability of being caught and suffering the disutility of losing the network, $\pi_2 \left[-F_2^v - \mathscr{V}_2 \right]$, or losing the crime opportunity and having to search for a new one, $\lambda \left[\mathscr{V}_1 - \mathscr{V}_2 \right]$.

The wholesaler progresses through three states: searching for a retailer, having a retailer and waiting for the retailer to discover an opportunity, or transacting with the retailer and facilitating the crime. The value of being in each state $i \in \{0, 1, 2\}$ is denoted $\mathscr{W}_i$. The flow Bellman equations for a wholesaler are

$$
\begin{aligned}
r\mathscr{W}_0 &= \pi_0 \left[-F_0^w - \mathscr{W}_0 \right] + \theta_0 q_0(\theta_0) \left[\mathscr{W}_1 - \mathscr{W}_0 \right], & (4) \\
r\mathscr{W}_1 &= \pi_1 \left[-F_1^w - \mathscr{W}_1 \right] + q_1(\theta_1) \left[\mathscr{W}_2 - \mathscr{W}_1 \right], & (5) \\
r\mathscr{W}_2 &= y_w + \pi_2 \left[-F_2^w - \mathscr{W}_2 \right] + \lambda \left[\mathscr{W}_1 - \mathscr{W}_2 \right]. & (6)
\end{aligned}
$$

The interpretation of the wholesaler's problem is similar to the retailer's with the exception of the matching function in the first stage and the payoff in the last. As wholesalers are matching with retailers, they find matches at rate $\theta_0 q_0(\theta_0)$. In addition, they receive the payoff $y_w \equiv y - y_v - y_p$ where y_v share of the surplus goes to the retailer and y_p is the exogenous cost of facilitating the transaction. In terms of cocaine trafficking, one can consider y_p as the cost of buying cocaine on a centralized market and the transport costs to distribute the drugs to the retailer. Using the same example, one can think of y as the reservation value of the cocaine user.

2.3 Bargaining, free entry and networking flows

In this section, I discuss three key characteristics of the model. I look at how the surplus is split between the wholesaler and retailer, how the free entry of retailers affects payoffs, and how the networking process influences the aggregate crime rate.

The contract between the retailer and wholesaler is determined by the generalized Nash solution. The contract satisfies

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$$y_v = \arg\max(\mathscr{V}_2 - \mathscr{V}_1)^\beta (\mathscr{W}_2 - \mathscr{W}_1)^{1-\beta}, \tag{7}$$

where the retailer's bargaining power is $\beta \in [0, 1]$. As for the free entry of retailers, it implies

$$\mathscr{V}_0 = 0. \tag{8}$$

The model can also be solved with a free entry condition for wholesalers as an alternative to a fixed size. The results are in the appendix.

The model's flows come in two types. The first is how retailers match with wholesalers and then match with crime opportunities. The second type of flows relates how the number of available crime opportunities are found and lost. In the steady-state, the mass of retailers flowing in and out of states 1 and 2 are

$$q_0(\theta_0)v_0 + \lambda v_2 = [\pi_1 + q_1(\theta_1)]v_1, \tag{9}$$

$$q_1(\theta_1)v_1 = (\pi_2 + \lambda)v_2. \tag{10}$$

According to (9), the mass of retailers who flow into the state where they match with crime opportunities must be equal to the number flowing out of the same state. The measure flowing into the state are those who just found a wholesaler, $q_0(\theta_0)v_0$, and those who just lost a crime opportunity but not their wholesaler, λv_2. The flow of individuals exiting the same state are those who have been apprehended plus those who found a new crime opportunity, $[\pi_1 + q_1(\theta_1)]v_1$. Similarly, (10) prescribes that the flows into and out of the state where crime is taking place must be equal.

The second set of flows captures the amount of crime taking place. Given criminals do not interfere with each other's activities and the quantity of crime opportunities is fixed, the total number of opportunities must equal the sum of those being taken (c_2) and the opportunities remaining available (c_1), or

$$c_1 + c_2 = \kappa, \tag{11}$$

where κ is the quantity of criminal opportunities. In addition,

$$\theta_1 q_1(\theta_1)c_1 = (\pi_2 + \lambda)c_2, \tag{12}$$

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or in words, the number of opportunities being found equals the number being lost in the steady state.

To reiterate, a crime opportunity can be thought of as a drug user who is continuously buying drugs. Hence, the quantity of crime on a per period basis is equivalent to the amount of opportunities being taken,

$$c_2 = \left(\frac{\theta_1 q_1(\theta_1)}{\theta_1 q_1(\theta_1) + \pi_2 + \lambda} \right) \kappa. \tag{13}$$

2.4 Equilibrium

The steady-state equilibrium of the model can be defined as follows.

Definition 1 *A steady-state equilibrium consists of $\{y_v, v_0, v_1, v_2, c_1, c_2\}$ such that retail surplus (y_v) satisfies (7); the mass of retailers in each state (v_0, v_1, v_2) satisfy the free entry condition (8), and the flows (9)-(10); and the mass of available and engaged crime activities (c_1, c_2) satisfy (11) and (12).*

Solving for the equilibrium can be done in steps. First, the share of the surplus going to the retailer can be deduced, y_v. Following the first step, two conditions arise from the free entry condition and the retailer flows. These two conditions lead to a solution of the two equilibrium levels of market tightness, (θ_0, θ_1). Once known, the quantity of crime can be solved as well as the mass of retailers at each level of the networking process.

In determining retailer's surplus, it is straightforward to reduce the flow Bellman equations of the retailer and wholesaler into functions of the model's parameters and market tightness, θ_0 and θ_1. Given the substitution, (7) implies the surplus of the crime going to the retailer is

$$y_v = \beta y + \frac{\pi_1(\pi_2 + r)(\beta F_1^w - F_1^v(1-\beta)) - \pi_2(\pi_1 + r)(\beta F_2^w - F_2^v(1-\beta))}{r + \pi_1}. \tag{14}$$

As the reader can see, the retail surplus is a weighted share of total output, βy, plus what I refer to as a distortionary term. Although the term seems cumbersome, it would be zero if the retailer and wholesaler faced symmetric problems, or $\beta = 1/2$ and they have the same costs from apprehension. Also, the term is simplified due to the fact that the utility gain from taking the crime opportunity is discounted at the same rate by both the wholesaler ($[\mathcal{W}_2 - \mathcal{W}_1]$) and retailer ($[\mathcal{V}_2 - \mathcal{V}_1]$). As a result, the equilibrium rates of matching do not affect the way the surplus is split.

Taking the retailer's share of the surplus as given, one can use the free entry condition to find

$$q_0(\theta_0) = \pi_0 F_0^v \frac{q_1(\theta_1)(r+\pi_2) + (r+\pi_1)(r+\pi_2+\lambda)}{q_1(\theta_1)(y_v - \pi_2 F_2^v) - \pi_1 F_1^v(r+\pi_2+\lambda)}, \tag{15}$$

which I refer to as the "Network Creation," or NC, curve. The NC curve captures the fact that, as the cost of being caught or searching rises, $\pi_i F_i^v$ for $i \in \{0,1,2\}$, fewer retailers enter the market and create new networks holding everything else constant. Equivalently, we see an increase in the matching rate, $q_0(\theta_0)$. In the same way, an increase in the retailer's surplus increases the mass of retailers, and as a result it becomes increasingly difficult for a retailer to find a wholesaler. In general, the NC curve captures how retailers enter the market, and more specifically, the rate at which they match within the networking process.

Similarly, the flows (9)-(12) imply a "Network Flow," or NF, curve

$$\theta_0 q_0(\theta_0) = \left(\frac{(q_1(\theta_1)\pi_2 + \pi_1\pi_2 + \pi_1\lambda)\theta_1}{(\theta_1 q_1(\theta_1) + \pi_2 + \lambda)} \right) \kappa. \tag{16}$$

The NF curve captures the relationship between the number of crime opportunities, κ, and the measure being committed given the inherent frictions retailers face when establishing a network and locating a crime opportunity.

The NC and NF curves, given y_v from (14), reduce the equilibrium to two equations and two unknowns. As a result, they can be used to prove the following proposition.

**Proposition 1** *An equilibrium exists and is unique if*

1. $0 < y_v - \pi_2 F_2^v$

2. $0 < \mathscr{W}_0$.

where y_v satisfies (14).

The proof is in the appendix. The two conditions for existence and uniqueness can be easily interpreted. Condition 1 states the surplus from the crime must outweigh the expected cost of apprehension. Note, the cost of being caught in the first two stages of networking are irrelevant to the existence and uniqueness of the equilibrium as the length of time spent in each state decreases to zero as the mass of retailers falls. Condition 2 captures the fact that wholesalers must have positive expected utility. It is a sufficient condition for $y_w > 0$.

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The equilibrium can be illustrated in a simple two dimensional diagram as seen in Figure 1. The figure captures the market tightness retailers face when looking for a wholesaler and finding a criminal opportunity. The illustration demonstrates how the NF curve slopes upward because if fewer retailers are searching for wholesalers, then fewer will be in the second stage looking for crime opportunities, i.e. a lower θ_1. This fact is driven completely by the flow equations. The second equilibrium condition, the NC curve, slopes downward because of the crowding out effect from the free entry condition. In other words, if θ_0 rises, then the profitability of entering the market falls as it becomes harder to find a match. If $q_0(\theta_0)$ falls, then the free entry condition requires an offsetting effect of $q_1(\theta_1)$ rising, or an increase in the speed of finding a criminal opportunity. As such, if it is easier to find a crime, then θ_1 must be lower.

Figure 1: Equilibrium Matching
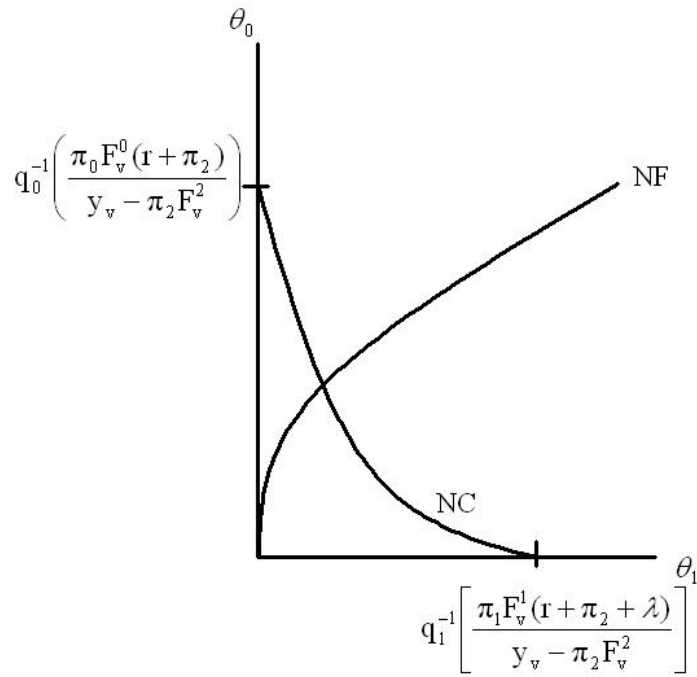
3 Policy

I begin by analyzing changes in the cost of apprehension, or F_i^j for $i \in \{0, 1, 2\}$ and $j \in \{v, w\}$. These comparative statics are simpler to analyze because they affect only the free entry condition, or NC curve. After examining the effects of increasing the costs of apprehension given the timing and target, I will look at the effects from altering the likelihood of apprehension, or π_i for $i \in$

$\{0,1,2\}$. The appendix discusses how to prove the following results.

3.1 Costs of apprehension

As discussed in the introduction, I consider a change in the players fixed costs.

Result 1

- *A change in F_0^w has no effect on y_v, the quantity of retailers, or crime.*

- *An increase in F_0^v decreases the quantity of retailers and crime while leaving y_v unchanged.*

Intuitively, F_0^w is a fixed cost to wholesalers who are making positive profits. Hence, altering it has no effect on crime.[6] The result changes if a free entry condition for wholesalers is introduced. For further discussion, refer to the appendix.

On the other side, the retail market has free entry. Therefore, an increase in F_0^v reduces future expected surplus and the number of retailers while leaving their share of the surplus unchanged.[7]

Policy makers can also increase the costs at the next stage of the networking process.

Result 2

- *An increase in F_1^w leads to an increase in y_v, the quantity of retailers, and crime.*

- *An increase in F_1^v decreases y_v, the mass of retailers, and crime.*

The most counter-intuitive result from a change in policy relates to increasing the cost of apprehension when the criminal network is established but not engaging in crime. The finding comes from the idea that the bargaining between the criminal types can be altered by anti-crime policies. In the extreme, an anti-crime policy can distort bargaining in a way that leads to an increase in crime.

The effect from a change in F_2^v and F_2^w is discussed in the section on efficiency.

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[6]The result is conditional on the fact the equilibrium exists, or Conditions 1 and 2 in Proposition 1 are satisfied. However, it is feasible to set F_0^w where a condition for existence is violated.

[7]The retailer's share of the surplus is unchanged because of the assumption on the timing of the bargaining. If the retail-wholesaler pair bargained over any future realization of a crime when they initially meet, then Result 7 would change. Therefore, the assumption on the timing of the bargaining plays a key role in determining how policy affects supply.

3.2 Likelihood of apprehension

Changing the likelihood of apprehension has two effects on the model. First, it can decrease the return to retailers, or specifically shifts the NC curve. Second, it destroys networks, inhibiting the amount of crime. In terms of the model, the NF curve shifts.

The model has been constructed to consider three different types of apprehension.

Result 3

- *An increase in π_0 decreases the mass of retailers and crime while leaving y_v unchanged.*

- *An increase in π_1 decreases y_v if and only if*

$$(1-\beta)F_1^v > \beta F_1^w$$

  If an increase in π_1 decreases y_v, then crime decreases.

- *Increasing π_2 decreases y_v if and only if*

$$(1-\beta)[F_2^v - F_1^v \frac{\pi_1}{r+\pi_1}] < \beta[F_2^w - F_1^w \frac{\pi_1}{r+\pi_1}].$$

  If an increase in π_2 decreases y_v, then crime decreases.

As in Result 1, π_0 is a fixed cost. Hence, an increase in π_0 increases the costs to the retailer, reduces their willingness to enter the market, and decreases crime.

Instead of inhibiting network creation through π_0, anti-crime policies can target existing networks by increasing π_1 or π_2. The results hinge on how the surplus is split. If y_v falls, then it guarantees a decrease in the retailer's surplus, a fall in the mass of retailers, or in other words a shift to the right in the NC curve. On the other hand, if y_v rises and a large mass of retailers enter the market, enough for the shift in the NC curve to outweigh the falling NF curve (which captures the destruction in matches), then it is possible for crime to increase.[8]

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[8]Note the condition for π_2 is nearly the opposite condition found in π_1. If $F_2^w = F_1^w$ and $F_2^v = F_1^v$, then π_1 decreases y_v if and only if π_2 increases y_v (and potentially crime).

4 Efficiency

In the standard search and matching model, efficiency is discussed in terms of the Hosios condition as found in Hosios (1990). In summary, bargaining power can determine the efficient level of market activity. In terms of a crime network with bargaining and build frictions, the efficient level of bargaining power is where the least amount of crime occurs.

Result 4 *If β decreases, then crime decreases.*

Hence, setting the lowest level of bargaining power results in the most efficient level or smallest amount of crime. Specifically, as β decreases, the surplus going to the retailer falls. As a result, fewer retailers enter the market and carry out criminal acts.[9]

Although it is interesting to consider changes in bargaining power, the applicable question is the relative effectiveness of government policies. For instance, how does raising F_2^w compare to raising F_2^y?

Result 5 *Increasing F_2^w or F_2^y by one unit decreases crime by equal amounts.*

The equivalence result might be surprising. However, bargaining again plays the key role. In other words, retailers help compensate the wholesalers by decreasing y_v when F_2^w increases. On the flip side, wholesalers compensate retailers by increasing y_v when F_2^y increases although not enough to completely offset the additional costs. In either case, bargaining guarantees any additional cost in the final stage is shared between each player and results in an equivalent drop in crime.

The equivalency result is not what the model predicts in general. Obviously, increasing F_1^w is inefficient relative to F_0^y, as it increases crime. Increasing F_0^w is not much better, as it does not affect the level of crime. Other comparisons of crime policies rely critically on the parameterization of the model and are excluded here. However, the comparisons raise the question about the most effective timing, target and type of anti-crime policies.

5 Discussion

As motivation, the model provides a new perspective on the U.S. cocaine market during the 1980's. Figure 2 illustrates two features of the market that are key to the model. Specifically, the model

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[9]Note that it is possible to set β high enough to make the wholesale monopolist's expected payoff negative and in turn eliminate the crime equilibrium.

predicts if the share of the surplus goes increasingly to the retailer due to an increase in the whole-saler's costs, then consumption will rise. In the data, we observe such a correlation where retailers were acquiring a larger share of the surplus at the same time consumption was rising.[10]

Figure 2: U.S. Cocaine Market
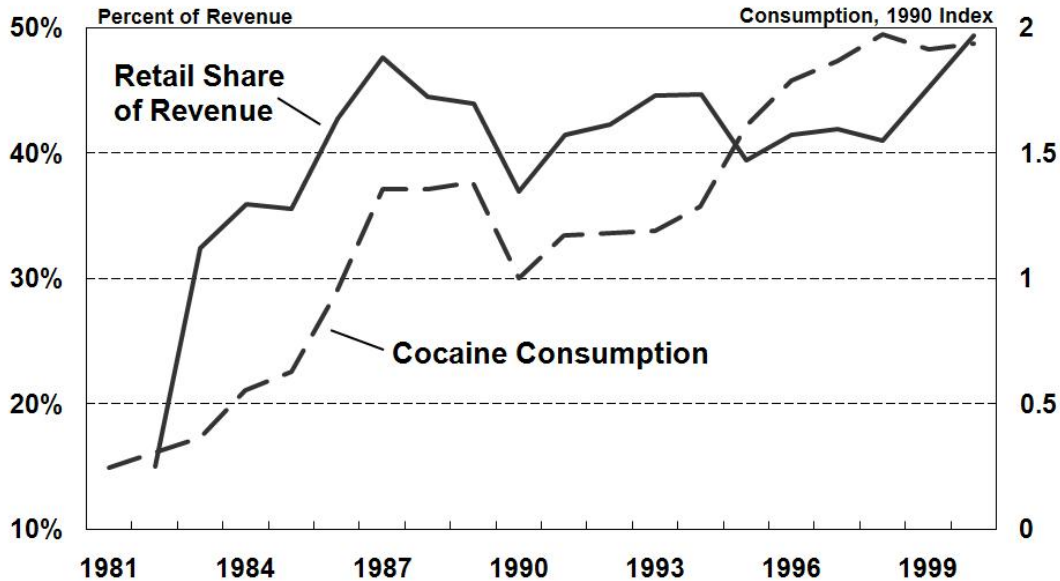
Source: Refer to Drug Abuse Warning Network (2002) for non-crack cocaine consumption proxied by the number of emergency room visits.[11]Refer to Office of National Drug Control Policy (2001) for retail share of revenue where a wholesale dealer is defined as selling 100 or more grams.

Although Figure 2 provides motivation for the model, the argument is not to say the "War on Drugs" distorted bargaining and increased consumption. To make such a statement, one would need to acquire accurate data on the suppliers' costs as well as test the model's predictions. How-ever, the data necessary to complete such an investigation is unavailable due to the illicit nature of the market. Nevertheless, I argue it is plausible that the "War on Drugs" increased drug consump-tion following Result 2. For the argument to hold, the proposition requires that the "War on Drugs" targeted the wholesaler by increasing the cost of apprehension after the retail-wholesale connection was made. In regards to targeting the wholesaler, the federal government's "War on Drugs" con-

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[10]Although I use a proxy for consumption and the price data has drawn criticism, it appears both the quantity consumed and share of retailer surplus rose during the 1980's.

[11]Non-crack cocaine is measured by the percent of mentions that state the substance was not smoked. I plot non-crack cocaine in order to control for the technological innovation of crack (smoked rather than insufflated) that is argued to have caused widespread use. Refer to Fryer, Heaton, Levitt & Murphy (2005) for further discussion.

sistently penalized wholesale dealers due to their jurisdiction being those trafficking across state lines. Also, Glaeser, Kessler & Piehl (2000) shows the Federal Government has a higher tendency to target high profile dealers. The second requirement is the "War on Drugs" needed to have been targeting dealers who had an established retail connection. The implication seems plausible as one of the main techniques used by the DEA is to have retail level dealers provide evidence against wholesalers after a crime has taken place.

In the end, the empirical evidence is insufficient to provide confidence in the claim that the "War on Drugs" increased drug consumption. However, the model provides an insight into how anti-crime policies can distort revenue sharing and potentially increase crime. This feature of the model is highlighted by the fact that we observe revenues going increasingly from the wholesaler to the retailer over the period when cocaine consumption increased drastically.

6   Conclusion

In this paper, matching frictions are incorporated into the formation of a network. In addition, the players within the network bargain over the surplus from committing crime together. These features demonstrate how the target, timing, and type of anti-crime policies can play a critical role in determining their effects. In the extreme, policies can increase crime. However, in general, we see increasing the expected costs of distribution will decrease crime.

As motivation, the model highlights the positive correlation between consumption and retailer's share of the surplus, a fact observed in the U.S. cocaine market during the 1980's. Specifically, the model demonstrates how the "War on Drugs" could have distorted the network's revenue sharing, a distortion that would lead to an increase in the number of retail dealers and consumption.

In considering further work, the model can be expanded to include a more complex networking process that includes additional bargaining and build frictions. Also, other applications can be considered such as the sequential search of illegal immigration and job matching. No matter the sophistication of the model or application, it appears the timing, targets and types of anti-crime policies will matter in determining the aggregate level of crime.

APPENDIX

A Proofs

Proof of Proposition 1 Equation (14) solves for y_v. Given y_v, one can think of the NC and NF curves in the space (θ_1, θ_0). In such a space, the NC curve has the properties

$$\frac{\partial \theta_0}{\partial \theta_1} < 0, \tag{17}$$

$$\lim_{\theta_1^+ \to 0} \theta_0 = q_0^{-1}\left(\frac{F_0^v \pi_0 (r + \pi_2)}{y_v - \pi_2 F_2^v}\right), \tag{18}$$

$$\lim_{\theta_0^+ \to 0} \theta_1 = q_1^{-1}\left(\frac{F_1^v \pi_1 (r + \pi_2 + \lambda)}{y_v - \pi_2 F_2^v}\right). \tag{19}$$

The NF curve has the properties

$$\frac{\partial \theta_0}{\partial \theta_1} > 0, \tag{20}$$

$$\lim_{\theta_1^+ \to 0} \theta_0 = 0, \tag{21}$$

$$\lim_{\theta_1 \to \infty} \theta_0 = \infty, \tag{22}$$

Hence, these two equations imply a unique solution to $\{\theta_1, \theta_0\}$ which can be used to solve for the remaining unknowns. ∎

Proof of Results 1-4 To solve for the comparative statics, first deduce the change in y_v from (14). Next, deduce the changes in the market tightness from the NC curve (15) and NF curve (16).

As the results are a straightforward exercise of total differentiation, I provide a simple example. Following the above steps, a change in F_0^v has no affect on y_v or the NF curve, which can be seen by differentiating (14) and (16) by F_0^v. However, the NC curve shifts back. Therefore, the equilibrium θ_1 and θ_0 falls, and from (13), crime falls. ∎

Proof of Result 5 Following the solution method above,

$$\frac{\partial y_v}{\partial F_2^w} = -\beta \pi_2, \qquad (23)$$

$$\frac{\partial y_v}{\partial F_2^v} = (1-\beta)\pi_2. \qquad (24)$$

Next, realize the NF curve is constant while the NC curve shifts according to

$$\frac{\partial NC}{\partial F_2^w} = -\pi_0 F_0^v \frac{r[\lambda + r + q_1(\theta_1)]}{[q_1(\theta_1)(y_v - \pi_2 F_2^v) - \pi_1 F_1^v(r+\lambda)]^2} \frac{\partial y_v}{\partial F_2^w} q_1(\theta_1), \qquad (25)$$

$$\frac{\partial NC}{\partial F_2^v} = -\pi_0 F_0^v \frac{r[\lambda + r + q_1(\theta_1)]}{[q_1(\theta_1)(y_v - \pi_2 F_2^v) - \pi_1 F_1^v(r+\lambda)]^2} (\frac{\partial y_v}{\partial F_2^w} - \pi_2)q_1(\theta_1). \qquad (26)$$

Therefore, plugging (23) and (24) into (25) and (26), respectively, results in an identical shift in the NC curve and an equivalent change in crime. ∎

B Wholesale Free Entry

In this section I discuss how the results change if one assumes a large measure of wholesalers that are given a decision to enter freely.

To begin, several equilibrium conditions do not change including the flows (9)-(12), how y_v is split (14), and the NC curve (15). However, I take free entry as changing the payoffs to the wholesaler, or

$$\mathscr{W}_0 = 0. \qquad (27)$$

In the same way as the free entry for retailers, the free entry condition for wholesalers results in a second NC curve, $NC_\mathscr{W}$, which mirrors the original NC curve except where the costs are the wholesaler's,

$$\theta_0 q_0(\theta_0) = \pi_0 F_0^w \frac{q_1(\theta_1)(r + \pi_2) + (r + \pi_1)(r + \pi_2 + \lambda)}{q_1(\theta_1)(y_w - \pi_2 F_2^w) - \pi_1 F_1^w(r + \pi_2 + \lambda)}. \qquad (28)$$

The additional equilibrium condition results in a similar proof of the existence and uniqueness of equilibrium as found in Proposition 1.

Proposition 2 *An equilibrium exists and is unique if*

1. $0 < y_v - \pi_2 F_2^v$

2. $0 < y_w - \pi_2 F_2^w$.

3. $q_0^{-1} \left(\frac{F_0^v \pi_0 (r + \pi_2)}{y_v - \pi_2 F_2^v} \right) > \Phi \left(\frac{F_0^w \pi_0 (r + \pi_2)}{y_w - \pi_2 F_2^w} \right)$.

where $y_w = y - y_v - y_p$ and $\Phi(\theta_0 q(\theta_0)) = \theta_0$.

Proof of Proposition 2 Equation 14 solves y_v and by definition y_w. Given y_v and y_w, one can think of the NC and NC$_{\mathscr{W}}$ curves implicitly in the space (θ_1, θ_0). In such a space, the NC curve has the properties specified in (17)-(19). However, the NC$_{\mathscr{W}}$ curve has the properties

$$\frac{\partial \theta_0}{\partial \theta_1} > 0, \tag{29}$$

$$\lim_{\theta_1^+ \to 0} \theta_0 = \Phi \left(\frac{F_0^w \pi_0 (r + \pi_2)}{y_w - \pi_2 F_2^w} \right), \tag{30}$$

$$\lim_{\theta_0 \to \infty} \theta_1 = q_1^{-1} \left(\frac{F_1^w \pi_1 (r + \pi_2 + \lambda)}{y_w - \pi_2 F_2^w} \right). \tag{31}$$

Hence, the NC and NC$_{\mathscr{W}}$ equations imply a unique solution to $\{\theta_0, \theta_1\}$ given conditions 1-3 of Proposition 2. Given $\{\theta_0, \theta_1\}$, the remaining unknowns can be solved. ∎

The first two conditions of Proposition 2 are interpreted in the same fashion as Proposition 1. The third condition guarantees there exists a point where NC and NC$_{\mathscr{W}}$ intersect.

As discussed in the text, allowing the free entry of wholesalers changes Result 1.

Result 6 *An increase in F_0^w decreases the quantity of crime while leaving y_w and y_v unchanged.*

Proof If F_0^w increases, then y_w, y_v and the NC curve remains the same. However, the NC$_{\mathscr{W}}$ curve shifts to the left thereby decreasing the equilibrium level of θ_1 and increasing θ_0. As a result, crime falls. ∎

After further analysis, one can also find crime falls if F_0^w or π_0 rises as is true with a fixed number of wholesalers. As for other parameters such as F_w^1, the results become increasingly dependent upon the parameterization of the model. As F_w^1 is critical to the analysis in the body of the paper, I analyze it here. To do so, I simplify the analysis by assuming the wholesaler and retailer face the

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same costs, the derivatives of the matching functions $\theta_0 q_0(\theta_0)$ and $q_0(\theta_0)$ are equal at $\theta_0 = 1$, and their bargaining parameter is identical, i.e. $\beta = 1/2$.

Result 7 *Assuming a symmetric market, an increase in F_1^v decreases the quantity of crime.*

Proof　Total differentiation of the system NC and $\text{NC}_{\mathscr{W}}$ implies

$$\frac{\partial \theta_1}{\partial F_1^v} = \frac{A_{1,1}b_2 - A_{2,1}b_1}{A_{2,2}A_{1,1} - A_{1,2}A_{2,1}}$$

where

$$
\begin{aligned}
\left|A_{1,1}\right| &= \left|\frac{\partial q_0(\theta_0)}{\partial \theta_0}\right| = \left|A_{2,1}\right| = \left|\frac{\partial \theta_0 q_0(\theta_0)}{\partial \theta_0}\right|, \\
A_{1,2} &= \pi_0 F_0^v \frac{\left((\pi_1 + r)(y_v - \pi_2 F_2^v) + \pi_1 F_1^v(\pi_2 + r)\right)(r + \pi_2 + \lambda)}{\left(q_1(\theta_1)(y_v - \pi_2 F_2^v) - \pi_1 F_1^v(r + \pi_2 + \lambda)\right)^2} \frac{\partial q_1(\theta_1)}{\partial \theta_1} = \\
A_{2,2} &= \pi_0 F_0^w \frac{\left((\pi_1 + r)(y_w - \pi_2 F_2^w) + \pi_1 F_1^w(\pi_2 + r)\right)(r + \pi_2 + \lambda)}{\left(q_1(\theta_1)(y_w - \pi_2 F_2^w) - \pi_1 F_1^w(r + \pi_2 + \lambda)\right)^2} \frac{\partial q_1(\theta_1)}{\partial \theta_1},
\end{aligned}
$$

by the assumption that wholesalers and retailers face the same market. However,

$$
\begin{aligned}
\left|b_1\right| &= \left|-\pi_0 F_0^v \frac{\left((\pi_2 + r)q_1(\theta_1) + (\pi_2 + r + \lambda)(\pi_1 + r)\right)\left(\frac{\partial y_v}{\partial F_1^v}q_1(\theta_1) - \pi_1(\pi_2 + r + \lambda)\right)}{\left(q_1(\theta_1)(y_v - \pi_2 F_2^v) - \pi_1 F_1^v(r + \pi_2 + \lambda)\right)^2}\right| > \\
\left|b_2\right| &= \left|-\pi_0 F_0^w \frac{\left((\pi_2 + r)q_1(\theta_1) + (\pi_2 + r + \lambda)(\pi_1 + r)\right)\frac{\partial y_w}{\partial F_1^v}q_1(\theta_1)}{\left(q_1(\theta_1)(y_w - \pi_2 F_2^w) - \pi_1 F_1^w(r + \pi_2 + \lambda)\right)^2}\right|.
\end{aligned}
$$

Therefore, the result follows that $\frac{\partial \theta_1}{\partial F_1^v} < 0$, and from (13), crime falls. ∎

Contrary to Result 2, it is optimal to increase F_1^v if the markets are nearly the same. However, the result fails to hold for alternative parameterizations of the model.

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